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## MICROSCOPIC STRUCTURE OF POTATO CHIPS<sup>1</sup>

R. M. REEVE AND E. M. NEEL<sup>2</sup>

Although various commercially processed potato products have been microscopically investigated (2, 3, 4, 6), apparently no descriptions of the cellular structure of potatoes fried in deep fat have been published. Certain conditions of deep-fat frying are known to produce blisters in potato chips and these blisters sometimes are filled with oil. The mechanism by which these blisters form has been little understood, but the results of recent preliminary studies suggest that they arise by cell separation in the interior of the slice (1). Likewise, little seems to be known about the manner in which the oil becomes distributed within either chips or French fries, whether it is localized or uniformly distributed throughout the slice.

This communication describes the microscopic structure of chips and French fried potatoes and includes observations on the formation of blisters and the distribution of the oil in potato chips.

### MATERIALS AND METHODS

Both commercial products and those experimentally produced at this Laboratory were used. The experimental samples were fried in cottonseed oil for 2½ minutes beginning at 380° F. and finishing at 320° F. for chips, and at 375° F. for 3 to 4½ minutes for French fries. Slice thickness for chips varied from 1/30 to 1/9 inch. Some samples were removed from the hot oil at different intervals in order to follow the sequence of blister development.

Sections for microscopic study were cut after the samples had been softened by soaking, first in ethyl alcohol and ether solution (2:1 by volume) for about 2 hours, to remove most of the oil, and then either in cold water for several hours or in hot water (about 180° F.) for 20 to 30 minutes. Several changes each were made of the alcohol-ether solution and of water to remove as much of the oil as possible and thus enhance the microscopic appearance of the sections. When sufficiently softened with water, pieces of the chips were placed on the flat surface of a block of paraffin and sectioned free-hand with a safety razor blade. Nearly all sections so cut were slightly wedge-shaped in 2 directions—the thicker portions being about 500 microns thick. This soaking procedure eliminated fracture of the cell walls that would occur with sectioning of the dry, brittle chips. Suitable sections of the blister areas of some of the chips also could be obtained by limiting the time of soaking in water so that the fragile blister walls were not overly softened and did not crumble when the sections were cut. Complete dehydration of these sections then occurred rapidly when they were placed in water for microscopic examination.

Other samples were soaked only in a 0.1 per cent aqueous solution of osmium tetroxide in a closed container to fix and stain their oil for

<sup>1</sup>Accepted for publication July 29, 1959.

<sup>2</sup>Western Regional Research Laboratory, Albany, California. A Laboratory of the Western Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture.

microscopic localization. Exceptional care was taken in working with this toxic reagent. Because of extremely intense staining of the tissue by osmium tetroxide, it was necessary to cut wedge-shaped sections and use only the thinner portions of the wedges for microscopic examinations. Other fried samples were partly softened with water, or with a solution of one volume each of glycerine, ethyl alcohol and water, then sectioned and the sections stained with a fat dye such as Sudan IV made up as a 1 per cent solution in 3 parts of 80 per cent alcohol and 1 part glycerine by volume.

Some of the chip samples treated with osmotic acid solution were embedded in polyethylene glycol wax according to the method developed by Spurr (5) for plant tissue. The osmium-fixed fats in the chips impeded infiltration of the water-soluble wax and many of the embedded samples crumbled badly when sectioned. When the infiltration schedule was prolonged, intact sections could be obtained from some embedded samples, however, at thicknesses ranging from 10 to 80 microns. These were mounted in a glycerine-gelatin preparation after careful removal of the wax as described by Spurr (5).

All photomicrographs were taken on a panchromatic film at low to medium magnifications.

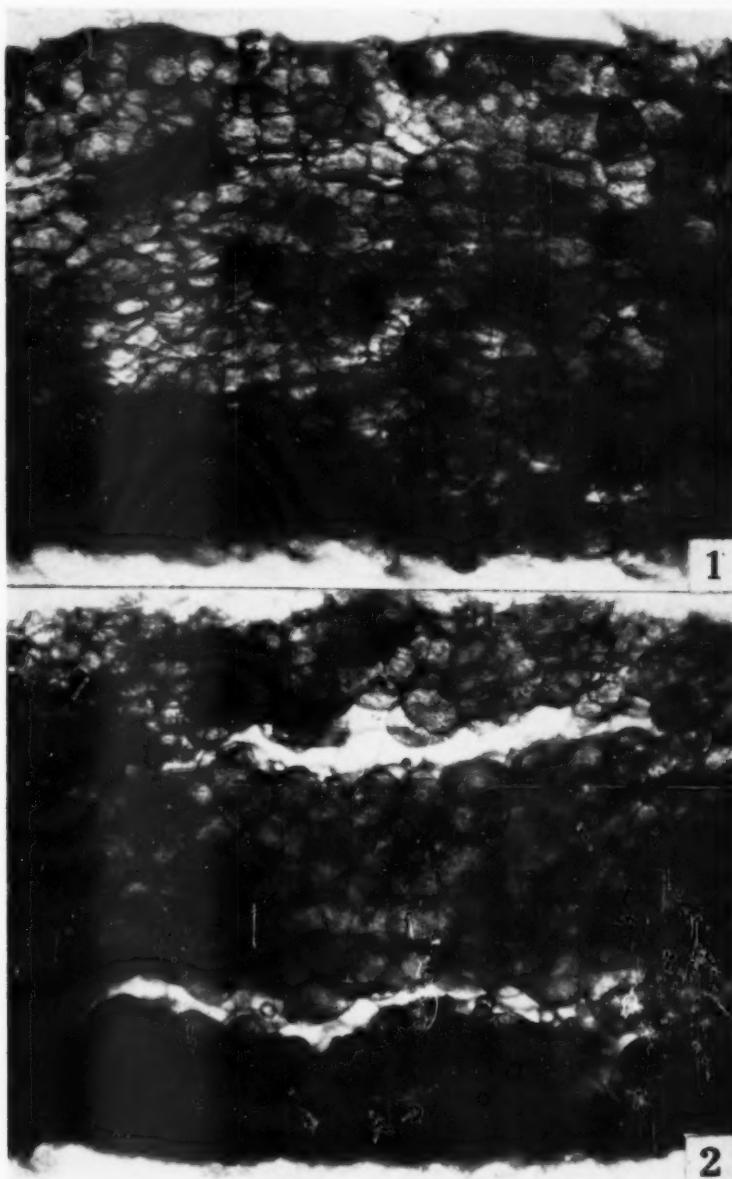
#### RESULTS

The microscopic structure of rehydrated potato chips is illustrated in Figures 1 to 4. All of the cells inside the original cut surfaces of the slices are intact; their starch content, first gelled and then dehydrated by cooking in hot oil, has been swollen by rehydration so that the cell walls are slightly distended and the cells have a rounded appearance. The tissue structure thus appears similar to that described elsewhere for steam-cooked potatoes (4, 6).

French fried potatoes display essentially the same tissue structure and differ from chips only in the degree of dehydration which the centers of the strips undergo when fried. In chips the slices become dehydrated throughout. The center of French fried strips do not completely dehydrate unless the strips are fried until brittle. The softer strips frequently could be sectioned without soaking treatment.

The microscopic appearance of the dry, brittle chip is the same as that previously described for dehydrated potato cubes which were sectioned after embedding in cellulose nitrate (3). The cells are shrunken and the cellulosic walls are wrinkled and convolute around the dried gelled starch content. In this shrunken condition the walls may appear to be fractured and, in fact, frequently do fracture when sections of chips and dehydrated cubes are cut in the brittle state. However, when the tissue is rehydrated the gelled starch swells and remains within the confines of cell walls. It is thus clearly evident that the walls have not been ruptured by the deep-fat frying process.

Figures 2 and 4 are different magnifications of sections cut through blister areas in chips after oil removal and rehydration as described. The blister area is clearly defined as one of localized cell separation. Figure 2 shows entirely 2 tiny blisters formed at opposite sides of a slice and Figure 3 is a portion of one of these blisters at higher magnification. Figure 4 is a section cut through the edge of a blister which measured over an



FIGURES 1 and 2.—Photomicrographs of unstained sections of rehydrated potato chips. Dark areas are thicker portions of section with some cells out of focus. Figure 2 shows 2 small blister areas formed by simple cell separation. 40X magnification.

inch in diameter. Search of the inner margins of blisters in a number of sections failed to reveal any evidence of ruptured cells other than those obviously produced by cutting the section.

Blisters were more readily produced in thick than in thin slices of potatoes. Chips produced from slices of 1/23-inch thickness contained no readily observed blisters although sections of these sometimes revealed minute blisters comparable with those in Figure 2. Such thin slices are only about 6 to 8 cell diameters thick. Chips produced from thicker slices increased blistering with increased thickness of slice. Slices of standard thickness (ca 1/18 inch) are about 10 or 12 cells deep. The starch in the outer cells of these and of thicker slices gels and becomes dehydrated more rapidly than that in the centers of the slices. Expanding steam is thus trapped, at first principally in the tiny intercellular spaces. As the middle lamella pectic substances between adjacent cell walls become softened and partially solubilized by the cook treatment, the cells are forced apart. Eventual escape of the steam is sometimes followed by movement of oil into the intercellular pocket thus formed.

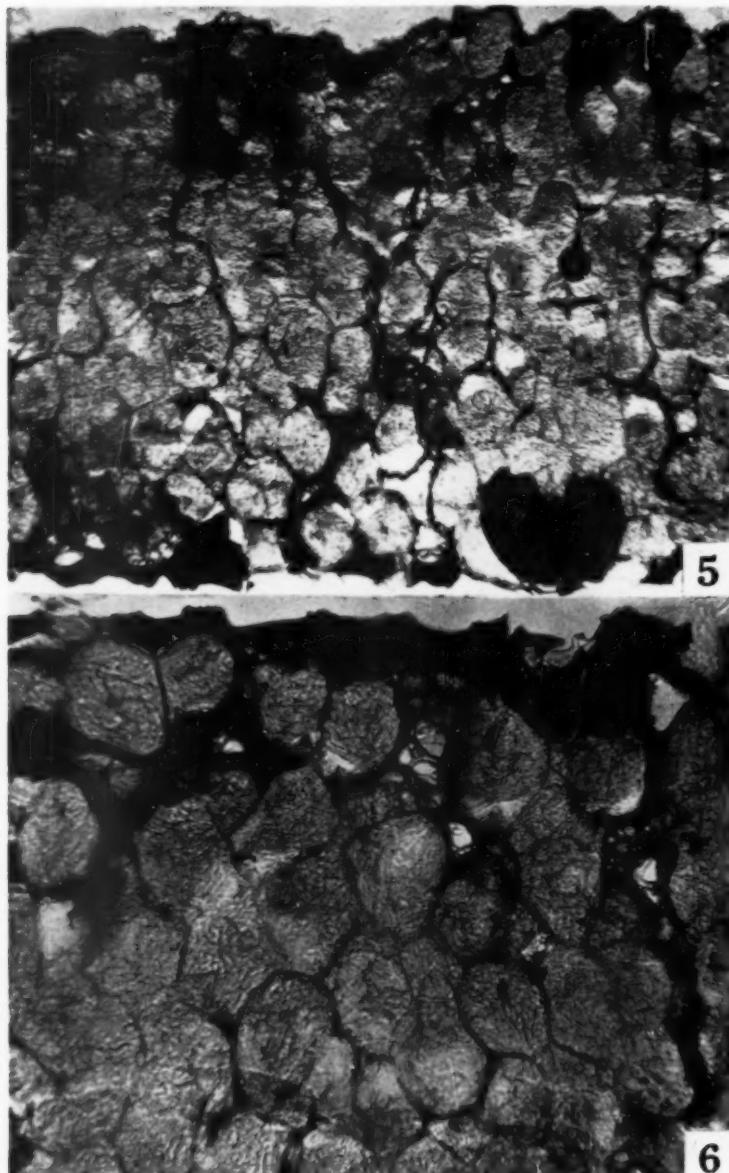
Figures 5 and 6 show sections of chips cut from samples embedded in polyethylene glycol after treatment with osmium tetroxide solution to stain the oil. The black areas are the oil deposits. Very similar, although less pronounced, oil staining was obtained with Sudan IV. With both staining treatments, a considerable amount of the oil is initially lost from the soaked chips before the staining reaction becomes pronounced. However, the osmium tetroxide method very soon produces a black, viscous soap which does not diffuse from its site and thus provides a reliable microscopic localization.

Osmium tetroxide penetrates tissues slowly. It did not blacken the centers of chips until at least 3 or 4 hours' exposure; then the structural detail became completely obscured by the stained oil. With only 2 hours' soak in the osmium tetroxide solution, as in Figures 5 and 6, sufficient of the chip centers remain unstained that differential distribution of the oil is more clearly revealed. Most of the stained oil appears to be in the cell walls and in minute intercellular spaces. The cell walls, in that they rehydrate more rapidly than the gelled starch contents of the cells (3), are also the route of the most rapid penetration of the osmium tetroxide solution.

Some completely blackened cells appear to be stained throughout, such as the 2 in the lower right of Figure 5. However, only some of these were found to contain large amounts of oil. When viewed in thick, free-hand sections in which these cells were intact, it was not possible to distinguish between surface views of stained, oil impregnated cell walls and those intact cells containing stained oil. When these whole cells were crushed, this distinction could be made. The gelled starch contents of many of these crushed cells showed only minute streaks of stained oil. Reexposure of such crushed cells to osmium tetroxide solution did not result in additional staining and it was thus evident that the original appearance of these was due to stained oil in the cell walls. Similar, although more finely divided staining with osmium tetroxide was obtained by treating crushed cells of freshly cooked potatoes. The cell walls of both raw and freshly cooked potato cells likewise were stained only faintly with the osmium tetroxide



FIGURES 3 and 4.—Photomicrographs of parts of blister areas in sections at higher magnification (100X). Figure 3 is of central part of upper blister in figure 2. Figure 4 is from a section through the edge of a blister about 1 inch in diameter. Note oil droplets (arrows) and cellular intactness.



FIGURES 5 and 6.—Photomicrographs of sections about 60 microns thick cut from chips first treated 2 hours with osmium tetroxide solution to stain the oil and then embedded in water-soluble wax. Black areas are oil deposits; note that they occur principally in cell wall areas and intercellular spaces. Figure 5 = 50X magnification; Figure 6 = 100X magnification.

solution except for the suberized cell walls of the periderm or skin and the lignified xylem walls which stained intensely.

Some intact cells in freehand sections of potato chips, however, did contain large amounts of stained oil. The appearance of such cells in thin sections cut from wax-embedded samples suggested that the initial dehydration effected by hot oil frying was more rapid than the swelling of the gelled starch. Thus, there was sufficient space for the oil to penetrate. Such cells with large amounts of oil were closely associated with the original cut surfaces of the tuber slices where, upon submersion in the hot frying oil, dehydration would be most rapid.

Sections cut through osmium-stained strips of French fries revealed little, if any, absorbed oil in the soft centers while the more dehydrated surfaces of the strips showed stained oil distribution comparable with that of the chips. It appears from these observations that oil distribution in both chips and French fries is not uniform, that the oil penetrates as water is removed, and that it is most abundant in the cellulosic walls and inter-cellular spaces. Presumably the gelled starch becomes relatively impervious to the oil as it dehydrates during the deep fat frying process, but some oil is able to penetrate a few surface cells between gelled starch granules before they swell and completely fill the cells.

#### DISCUSSION

The effect of deep fat frying on the cellular structure of potato tissue may be directly compared with the changes which have been previously described for cooking and dehydration processing (2, 3, 4). Potato starch granules gel readily at 65° to 70° C. At cooking temperatures the granules rapidly hydrate and swell excessively. Rapid dehydration during cooking, as occurs with deep fat frying, curtails this swelling process so that the cell walls do not become ruptured as sometimes occurs with the ordinary cooking of potatoes. As the gelled starch shrinks, water is partly replaced with oil in the frying process and the tissue becomes brittle. The shrunken cells of the finished chip are intact and similar in appearance to those of dehydrated potato products. Thicker pieces of potato tissue, as in French fries, have an outer shell of more completely dehydrated cell layers surrounding the cooked, less shrunken cells of the central, more moist tissue.

Although it might appear that the extreme conditions of deep fat frying would result in a considerable number of ruptured cells, no evidence could be found of any ruptured cells resulting from this process. It remains possible, however, that a very few cells might be ruptured in the initial contacts of the raw slices with the hot oil since even ordinary cooking to doneness ruptures some cells (sometimes about 2 to 3 per cent) as a result of swelling of the gelled starch content (4). Further, fully fried chips could not be sectioned after softening in water, as accomplished here, were there any appreciable frequency of ruptured cells. In fact, large numbers of ruptured cells in potato chips would probably cause the soaked chips to disintegrate into a pasty sediment. The demonstration that blistering in potato chips is a result of separation of intact cells is conclusive evidence that cell rupturing rarely occurs, if at all, with this process.

Blister formation in potato chips is similar to certain phenomena which have been described for dehydrated potato products. For example, when potato cubes are blanched prior to drying, the middle lamella pectins are

softened. A certain amount of "case hardening" sometimes occurs during hot air dehydration of the blanched cubes so that steam is trapped internally and its expansion results in cell separation and the formation of porous, opaque areas—the "popcorn" effect described elsewhere (4). Simple cooking induces cell separation in potato tissues and cell separation may be induced by excessive cooking in other vegetables and fruits without causing a physical breakdown of their cellulosic walls. In the case of potato and other high starch tissues, the swelling and hydration of the cooked, gelled starch may be sufficient to rupture some cell walls. Other evidence of broken cells in cooked fruits and vegetables, however, are traceable to artifacts of techniques in preparation for microscopic examination (3, 4, 6).

Excessive blistering is undesirable because chips break too readily to be suitable for "dips" and also because some blisters may contain large amounts of oil which impair chip flavor and render the product greasy when the blisters are broken in the package. Chips prepared from very thin slices which do not blister also are too fragile. Thicker slices, cut in corrugated form, do not blister because the central tissues of the slice are close to cut surfaces and the expanding steam can readily escape before the surfaces are sealed. The textural qualities of potato chips and French fries are thus influenced by readily observed effects of processing on cellular structure and can be manipulated. More needs to be learned about the practical limits of manipulation in relation to its influence on other characteristics of these products.

#### SUMMARY

Microscopic examination of potato chips and French fries has provided conclusive demonstration that the cellular structure remains intact and that the cell walls rarely, if ever, rupture during the deep-fat frying process. Blistering of chips is a result of simple cell separation due to expansion of steam trapped within the slices when the surface become dehydrated and sealed. Deep-fat frying is essentially a cooking and dehydration process during which the starch content of the cells is gelled and dehydrated and and some of the water in the tissue is replaced with oil. Most of the oil in finished chips is distributed in the cell walls, inter-cellular spaces and blister areas. Apparently much less of the oil present in chips is held between the gelled starch granules within the cells although oil penetrates some intact cells at the original surface of the slices.

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## A NONDESTRUCTIVE TECHNIQUE FOR DETECTING INTERNAL DISCOLORATIONS IN POTATOES<sup>1</sup>

G. S. BIRTH<sup>2</sup>

### INTRODUCTION

Internal discoloration is one of the major defects of potatoes. Previously it has been impossible to evaluate accurately the degree of discoloration of a tuber without cutting it. A nondestructive method of determining the discoloration would make it possible to remove the discolored tubers from a given lot of potatoes and thus improve the over-all quality. This paper describes the application of light-transmittance techniques to detecting internal discolorations in potato tubers with particular emphasis on hollow heart.

Most efforts directed toward detecting internal defects in potatoes have been attempts to detect hollow heart. Size grading and specific gravity can be used to indicate severe hollow heart, but these techniques are not sufficiently accurate to be practical (4). In 1937 Harvey (2) reported an attempt at using egg-candling lamps and X-ray equipment to detect hollow heart. However, in these investigations the researcher was looking for the image of the void or the hollow in the potato. It is possible to view an image of the void when X-rays are used, but the cost of X-ray equipment has hindered the development of this technique for the hollow heart problem. An image of the void cannot be seen when visible or near infrared energy is used, but there is a selective absorption of energy in the near infrared region which is indicative of hollow heart. This selective absorption of energy is due to the discoloration in the vicinity of the void.

### MATERIALS AND METHODS

The data presented in this paper were secured with the Rephobiospect, a specially designed spectrophotometer for recording spectral absorption curves of biological materials. This instrument as described by Norris (3) recorded spectral curves on a linear energy scale. It has since been modified to record on a logarithmic energy scale and a new method of presenting the sample has been developed. The use of an integrating sphere to enclose the sample for recording spectral absorption curves of biological materials has proven satisfactory for most applications; however, in the case of detecting hollow heart the direct phototube mount shown in Figure 1 is better. This alternative apparatus measures only the light passing through the center of the tuber giving the technique more sensitivity to small discolored areas located near the center of the tuber. The potato is oriented in the instrument so the light passes through the shortest dimension of the potato. The phototube housing is mounted on a vertical shaft so this portion of the assembly can be raised to insert a potato for measurement. A telescoping housing encloses the potato to exclude all ambient light.

<sup>1</sup>Accepted for publication October 5, 1959.

<sup>2</sup>Quality Evaluation Section, Biological Sciences Branch, Agricultural Marketing Service, United States Department of Agriculture, Beltsville, Maryland.

The phototube housing rests on the potato while the measurement is made; thus, the vertical position of the phototube is an indication of the size of the potato. A scale was placed at a convenient location so the size of potato could be recorded when the transmittance measurement was made.

Normal practice in spectrophotometry uses the ratio between the energy incident on a sample and the energy transmitted as the index of composition of the sample. In measuring the transmittance of agricultural products this ratio is a function of size as well as composition. Information can be gained about the composition of the sample by using an index which indicates the shape of the absorption curve. Figure 2 shows the spectral absorption curve of a sound potato (Curve A) and one with hollow heart (Curve B); Figure 3 is a photograph of these potatoes. In recording the curves the minimum absorption (800 m $\mu$ ) is arbitrarily given the value of zero optical density, and all other points are plotted in reference to this value. Both curves include the system response of the Rephobiospect. The potato with hollow heart absorbs considerably more energy in the 650 m $\mu$  to 750 m $\mu$  region than the sound potato. The optical density difference between 800 m $\mu$  and 710 m $\mu$  [ $\Delta$  OD (800-710)] gives an indication of the shape of the curve in this part of the spectrum and can be used to indicate hollow heart. The selection of these wavelengths is desirable because both are at an absorption minimum; thus, there is a maximum amount of energy available and the measurement is least affected by other compositional factors.

Two tests were made to demonstrate the ability of this technique to detect hollow heart and other discolorations. The procedure followed in these tests was to place the washed potato in the Rephobiospect and record the  $\Delta$  OD (800-710) and size. Then the tuber was removed and cut. A visual evaluation of the hollow heart was made on a scale of 0 to 3; *i.e.*, 0—no hollow heart; 1—small void, very slight discoloration; 2—medium hollow heart; 3—large hollow heart. The presence of blackspot, greening or decay was noted. In the analysis of the data a dividing line was selected and potatoes having a  $\Delta$  OD above this value were termed accepted and those having a  $\Delta$  OD below the dividing line, rejected. The location of the dividing line was selected to give the best fit between the  $\Delta$  OD values and the visual observations of the potatoes.

#### RESULTS

The first test was made with Katahdin potatoes. Figure 4. Of the 68 potatoes in this test 81 per cent of those with discolored tissue were rejected and 10 per cent of the sound potatoes were rejected. Considering the types of discoloration separately, 83 per cent of the hollow heart potatoes were rejected. The hollow heart potatoes which were accepted had very slight discoloration and could probably be considered acceptable for some purposes. Fifty per cent of the potatoes with greening were rejected and one of two potatoes with decay was rejected. The rejection rate for these defects is lower because decayed areas and greening occur at random locations on the tuber and the apparatus has been designed to look at a cylinder of tissue through the center of the tuber. Blackspot occurs at random locations in the tuber also, but in this test the potatoes with blackspot had a fairly large amount of discolored tissue; *i.e.*, approxi-

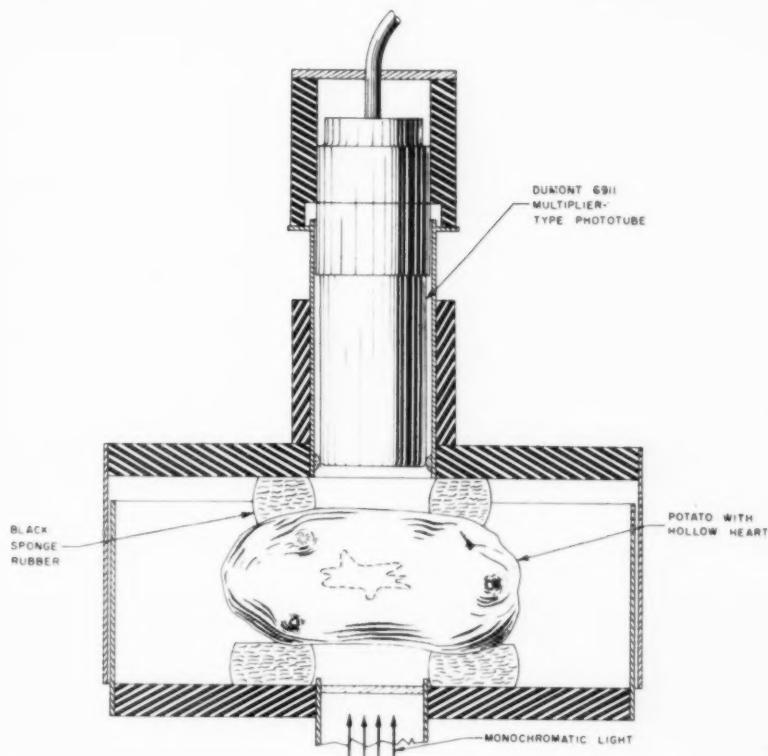


FIGURE 1.—Direct phototube mount designed for detecting hollow heart. Note that the hollow heart appears directly between the light source and the phototube.

mately 10 per cent of the tuber; hence, 88 per cent of the blackspot potatoes were rejected.

In the second test for detecting hollow heart (Figure 5, Irish Cobbler potatoes with 61 per cent hollow heart) there was appreciably more discoloration associated with the hollow heart; thus, 98 per cent of the hollow potatoes were rejected and 9 per cent of the sound potatoes were rejected. There were 91 potatoes in this test and very few defects were noted except hollow heart.

The  $\Delta OD$  (800-710) value varied from .10 to .39 or a range of .29 for the sound Katahdin potatoes and from -.08 to -.44 or a range of .36 for the sound Cobblers. The slightly greater variation in the  $\Delta OD$  of the sound Cobblers may have been caused by a considerable variation in the size and shape of these potatoes whereas the Katahdins were quite uniform in this respect. There is a marked difference between the average  $\Delta OD$  for the sound potatoes in the two tests: .29 for the Katahdins and -.21 for the Irish Cobblers, due largely to the fact that

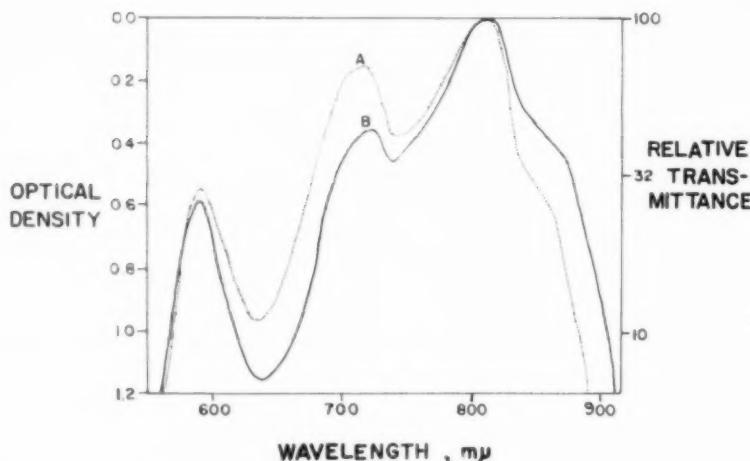


FIGURE 2.—Spectral absorption curves of a sound potato, curve A; and a potato with hollow heart, curve B.



FIGURE 3.—Potatoes used for recording curves shown in Figure 2. The potato at the left weighed 290 grams, and had a specific gravity of 1.082. The potato on the right weighed 311 grams and had a specific gravity of 1.065.

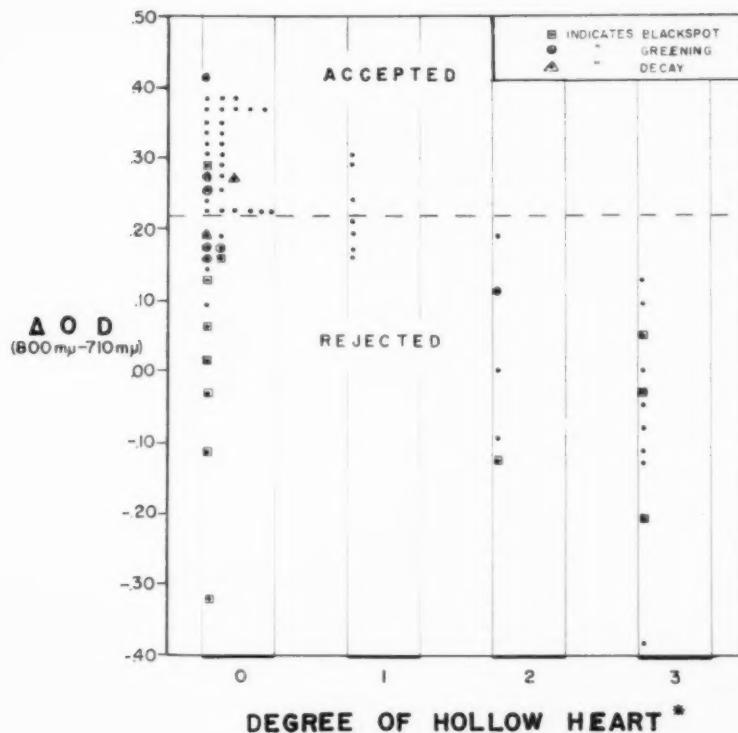


FIGURE 4.—Test for detecting hollow heart of Katahdin potatoes.

\*Degree of hollow heart is a subjective evaluation of the defect.

- 0—No hollow heart
- 1—Small void, very slight discoloration
- 2—Medium hollow heart
- 3—Large hollow heart

the Cobblers had been held in storage for several months at 40° F. and the flesh had become yellow. Yellowing of the flesh is not a serious problem for this technique because several months of storage are required to develop appreciable yellowing, and the yellowing appeared to be the same for all potatoes of a single variety held in storage under the same conditions.

Because the absorption characteristic of the potato skin is similar to the absorption characteristic of the discoloration associated with hollow heart, the size of the tuber was found to be a factor in the detection of hollow heart. The path length of the light through the skin constitutes a larger proportion of the total path length for small potatoes than for large potatoes, so the small tubers tend to be rejected. In Figure 6 is plotted the  $\Delta OD$  (800-710) *vs.* size for Irish Cobbler potatoes. These data are based on fresh Cobblers which had not yellowed and did not have any

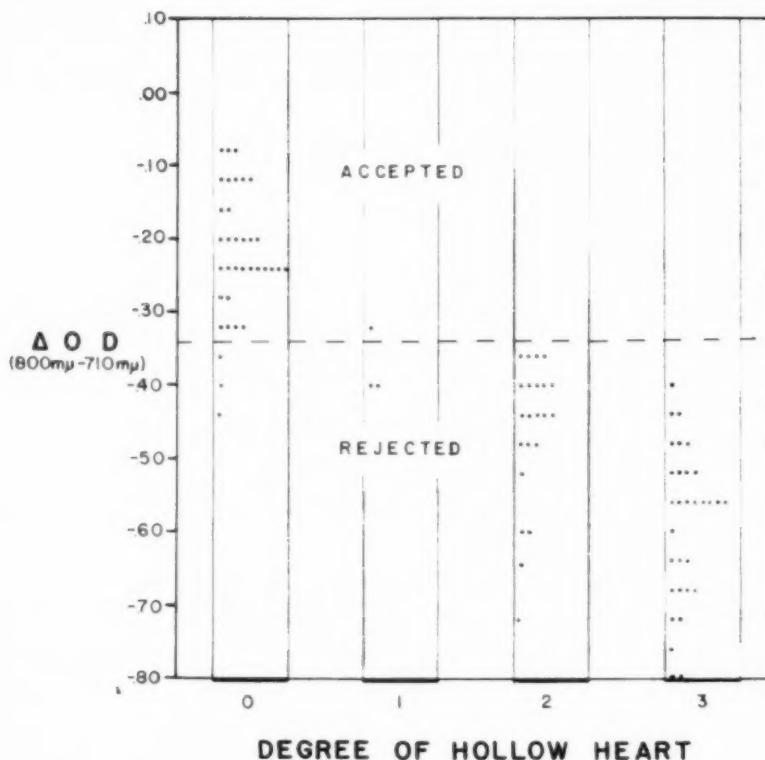


FIGURE 5.—Test for detecting hollow heart of Irish Cobbler potatoes.

internal discoloration. The average  $\Delta OD$  for these potatoes is .14 compared with .29 for the sound Katahdins, indicating that variety influences the  $\Delta OD$  somewhat. Other variables which affect the measurement and are likely to cause errors are: variations in the spectral absorption of the skin, scarred tissue, and soil on the tubers. The flesh of sound potatoes, not discolored, did not appear to cause any variability. Approximately 4 days of storage at 40° F. and 60 foot candles of illumination causes the formation of sufficient greening to affect the  $\Delta OD$  significantly. The reproducibility of the  $\Delta OD$  measurement for an average sound potato is  $\pm .019$  (1 standard deviation).

#### DISCUSSION

Emphasis has been placed upon the detection of hollow heart in this work since this is a defect which occurs at a predictable location in potato tubers. By developing an apparatus which examines just the portion of the tuber where the defect is likely to occur, very good results can be obtained

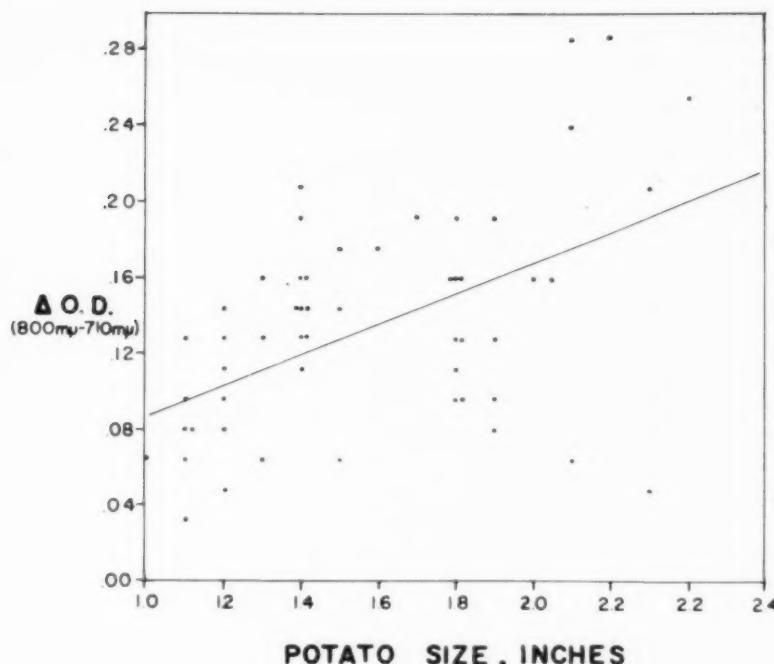


FIGURE 6.—Effect of size on the measurement of  $\Delta$  O.D. ( $800 \text{ m}\mu - 710 \text{ m}\mu$ ). Potato size is the shortest dimension through the center of the potato.

in detecting hollow heart. An apparatus for detecting all internal discolorations reliably is quite possible. Such a device might consist of a number of phototubes looking at various portions of the tuber.

For practical purposes the measurement of  $\Delta$  OD can be made very rapidly so the technique could be used in automatic sorting. A similar measurement has been applied to detecting blood spots in eggs (1) where an automatic sorting apparatus sorts the eggs at the rate of 2 a second. This device has been shown to be economically feasible as compared to hand candling of eggs and is appreciably more accurate. The total cost of sorting and packing eggs when using electronic bloodspot detection is 0.12 cents per egg. This is a rough estimate of what the added cost for each potato would be to sort the potatoes automatically for internal discolorations.

#### SUMMARY

A technique of nondestructively detecting internal discoloration in potatoes by light transmittance has been described. Preliminary investigations with hollow heart indicated that the discolored tissue exhibited a selective absorption of energy at  $710 \text{ m}\mu$ . A measurement of the optical

density difference between wavelengths at 800 m $\mu$  and 710 m $\mu$  is used as the indication of discoloration. This measurement indicates discolorations associated with hollow heart, blackspot, and greening; however, the apparatus used in this study was designed to examine potatoes for hollow heart. Results of limited tests showed that the method detected the presence of hollow heart 98 per cent of the time in a group of Irish Cobbler potatoes containing 61 per cent hollow heart. In a test with Katahdin potatoes 81 per cent of all discolored tubers were detected including potatoes with decay, greening, blackspot and hollow heart.

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## RESISTANCE OF POTATO TO INFECTION BY MECHANICALLY INTRODUCED VIRUS X<sup>1</sup>

AUGUST E. KEHR AND JAMES C. HORTON<sup>2</sup>

The importance of virus X in the Irish potato arises from the widespread distribution of the virus, the yield depression it causes, and a general occurrence of mild or masked strains (4). A common name of the disease, "latent mosaic" testifies to this situation. Of major importance therefore was the description by Schultz and Raleigh (11) of potato seedlings exhibiting high resistance to mechanical inoculation with virus X. In 1934, one of these seedlings, 41956, was found to be highly resistant (9) and was described as immune in 1937 (10). This one seedling has served as a basis for present-day virus X immunity work and successful hereditary transmission of this character is exemplified by many unnamed immune seedlings and the varieties Saco and Tawa.

Since 1933, numerous attempts to transfer virus X particles mechanically into 41956 or its derivatives have failed to adequately disprove immunity. An exception is the work of Hutton and Wark (6), who reported recovery of infectious particles from an immune derivative of 41956 three weeks after mechanical inoculation with virus X. Despite this report, the prevailing concept is complete immunity from infection by mechanical inoculation.

Passage of infectious material through intermediate scions of 41956 has been demonstrated by grafting techniques (3) and recovery of infectious particles from roots and stems of various immune hosts when mechanically inoculated to indicator plants has likewise been reported (2). Scions of virus-X-infected varieties, when grafted to stocks of immune varieties, respond by producing aerial tubers (7), a reaction employed as a criterion of immunity. Although slight necrosis is sometimes associated with a graft to a virus-X-infected stock (1), this is not usually considered to be infection of the immune host (8).

A definition of immunity for purposes of this paper is predicated on a lack of infection, and infection in turn implies establishment and multiplication within the host. To date, no evidence has been presented which demonstrates multiplication of virus X within an immune host except by Hutton and Wark (6). Hypersensitivity would assume limited development of the virus within the host; less development than possible in a susceptible host, but more development than possible in an immune host. Hutton and his co-workers have postulated that immunity and hypersensitivity are controlled by identical factors, (5, 6) but adequate details of either situation are not available for critical analysis.

Inheritance of characters for virus X immunity has been described by several workers. Hutton and Wark (6) postulated that a recessive gene in

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the nulliplex condition provided immunity and that the allelomorphic dominant gene in a quadriplex condition gave complete susceptibility. It is to be inferred that the simplex, duplex, and triplex genotypes result in varying levels of resistance, but never immunity. Stevenson, Schultz, and Clark (12) postulated a tetrasomic inheritance, by which immunity of 41956 is conveyed by two complimentary dominant genes, one duplex and one simplex. They designated these as genes A and B and suggested A<sub>1</sub>A<sub>2</sub>B<sub>1</sub>B<sub>2</sub> as the genotype for 41956. Interpolation of this hypothesis suggests genotypes A<sub>1</sub>—B<sub>1</sub>B<sub>2</sub> and a<sub>1</sub>a<sub>2</sub>B<sub>1</sub>—a<sub>1</sub>a<sub>2</sub>B<sub>2</sub> would all be susceptible to virus X. If correct, it should be feasible to hybridize two susceptible genotypes A<sub>1</sub>—B<sub>1</sub>B<sub>2</sub> and a<sub>1</sub>a<sub>2</sub>B<sub>1</sub>—a<sub>1</sub>a<sub>2</sub>B<sub>2</sub> and obtain resistant segregates by recombination in the progeny. To date no such example has been reported and prior to this report no data have been published demonstrating that virus X immunity appeared in the progeny of two parents known to be susceptible. This paper describes a cross in which virus X resistance or immunity, apparently similar to that found in 41956, appeared in the segregating progeny of two virus X-susceptible varieties.

#### MATERIALS AND METHODS

*Parents:* The potato clones X 927-3 and B 2903-17 were both developed by the U. S. Department of Agriculture in the program of potato improvement. Both are white-skinned and late maturing and show some resistance to the leaf roll virus. The cross was made initially to combine the leaf roll and mild mosaic resistance found in X 927-3 with the scab, late blight and leaf roll resistance of B 2903-17, the latter being used as the pollen parent. X 927-3 and B 2903-17 have been tested repeatedly by several independent workers for their reaction to virus X and without exception have been shown to be susceptible to all the commonly occurring strains of the virus.

*Progeny:* Seedlings from the cross, X 927-3 x B 2903-17 were first grown in the fall of 1954 under the pedigree number Ia 1336. Eight hundred and twenty-six seedlings, all survivors of a routine late blight screening test were grown. Of this number, 74 were planted in leaf roll cages. The remaining 752 plants of progeny Ia 1336 were grown in 3-inch pots in the same greenhouse (but on a different bench) with plants of other progenies which had been inoculated with a severe strain of virus X. In some unknown manner, virus X was spread from the inoculated plants to plants of Ia 1336 and other previously uninoculated, but supposedly susceptible, plants. Seedlings on both sides of and directly adjacent to Ia 1336 showed distinct symptoms, but plants of progeny Ia 1336 developed no detachable symptoms. Half of the plants of this progeny were then individually mechanically inoculated by using a mixture of carborundum and juice expressed from virus-X-infected *Nicotiana glutinosa* L. Approximately 2 weeks later, 9 plants showed symptoms of virus X infection and later a serologic test confirmed the presence of virus X. From the population showing no symptoms, 30 plants were randomly selected, and all tested negatively by the serologic test. From these results it was concluded that some of the progeny of pedigree Ia 1336 were highly resistant to infection with virus X, but no further attempt was made to identify this resistance and the plants subsequently were lost. The cross, X 927-3 x B 2903-17 was repeated later under pedigree number Ia 55328.

**Pedigrees:** An investigation was started to discover the possible origin of virus X resistance in the cross of X 927-3 and B 2903-17. The pedigree of these two clones were examined for the presence of clones known to possess virus X immunity. Unfortunately, many of the potato clones found in the pedigrees are no longer available, and their virus X reaction could not be ascertained. However, where this information is available, it is indicated in Figures 1-3 by the symbol (S) for clones which were tested in this study and have a known susceptibility to virus X. No plants were found in either pedigree with known or demonstrated immunity from virus X.

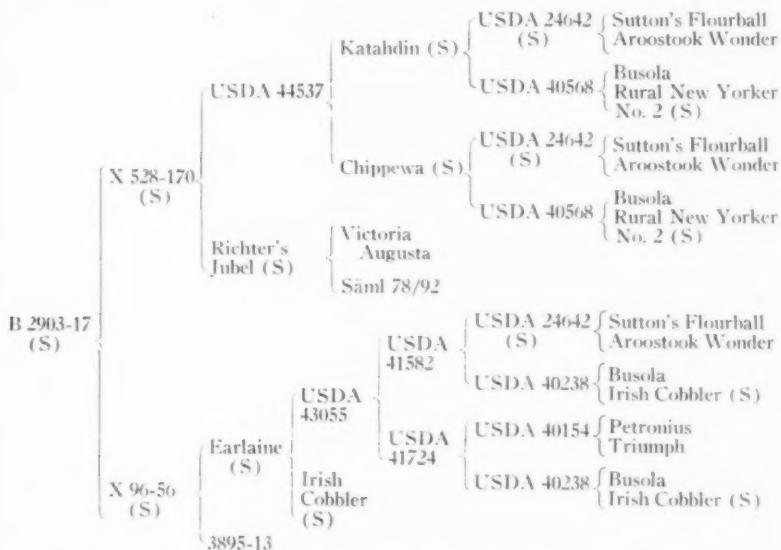


FIGURE 1.—Pedigree of B 2903-17. Clones tested for virus X reaction and found susceptible are indicated (S).

## RESULTS

In the fall of 1957, an additional planting of seedlings was made from the cross of X-927-3 and B 2903-17 under the pedigree Ia 55328 and a population of 380 plants was obtained. When these seedlings were 6 inches high, they were mechanically inoculated with infectious juice from *N. glutinosa* L. After each inoculation, plants showing visible symptoms were discarded. Survivors were subjected to several cycles of selection and some have been inoculated five times. High titers of virus X particles were present in all cases as demonstrated on *Gomphrena globosa* L. After an adequate incubation period at 70 degrees F., leaves from seedlings showing symptoms were macerated and rubbed on carborundum-dusted *G. globosa* leaves. Each time an additional inoculation was made, some of the seedlings became infected, indicating the presence of a high level of resistance. However, after five inoculations, some seedlings still did not show

symptoms and when sub-inoculations were made on *G. globosa*, no local lesions appeared. These survivors were therefore considered very highly resistant or immune. Tubers of these seedlings were sent to colleagues for testing. Reports from these colleagues have confirmed the findings that these seedlings are highly resistant to infection by mechanically introduced virus X.

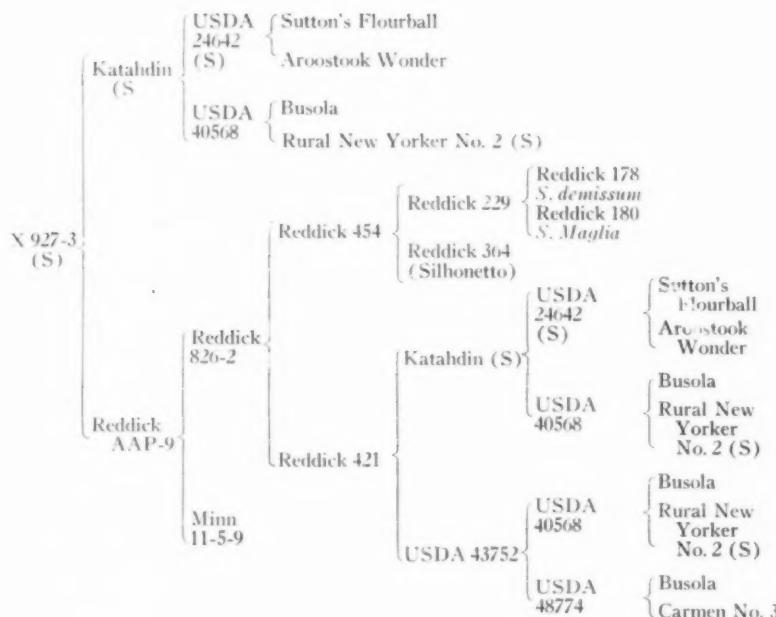


FIGURE 2.—Pedigree of X 927-3. Clones tested for virus X reaction and found susceptible are indicated (S).

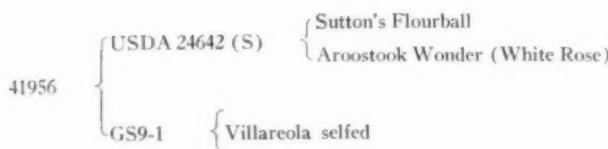


FIGURE 3.—Pedigree of 41956. Clones tested for virus X reaction and found susceptible are indicated (S).

## DISCUSSION

Seedling 41956, discovered in 1933, provided a source of virus X immunity for potato breeders which has been transmitted to two named varieties and many unnamed seedlings. The spontaneous appearance of the immunity in 41956 is even less astonishing than the fact that this event has been unique up to the date of the present report. No other sources of immunity have been described in *Solanum tuberosum* L. since 1933, when immunity occurred in the progeny of the cross, Reddick's Selection GS-9 ♀ by U.S.D.A. selection 24642 ♂.

Stevenson, Schultz, and Clark (12) postulated that only a single dominant A gene and a single dominant B gene need be combined to provide immunity from virus X. Assuming a normal chromosome distribution, a cross of the two susceptible genotypes, A---bbbb and aaaAB--- could be expected to provide by recombination at least 25 per cent immune seedlings with a genotype of A---B---. In view of the high percentage of immune seedlings which could theoretically occur, it is somewhat astounding that this theory has hitherto been neither confirmed nor disproved.

The source of virus X immunity in 41956 has never been adequately ascertained. A common consensus is that immunity was introduced from the variety Villareola, an importation from Central America. This opinion must remain conjectural because the virus X reactions of Villareola and of the seedling derived from Villareola selfed cannot be determined since all these clones are lost so far as the authors know. Further, with the lack of specific data concerning the virus X reaction of clone GS-9, it cannot be stated positively that the virus X immunity in 41956 arose *de novo* from a cross between two susceptible parents, although this assumption has been the generally accepted explanation. Since Villareola does not appear in the pedigrees of either B 2903-17 or X 927-3, the virus X immunity in progeny Ia 1336 must have arisen from some other source. The immunity in 41956 may likewise not have arisen from the variety Villareola, but by genetic recombination from some other source common to 41956, B 2903-17, and X 927-3, such as 24642, which appears in all three. Seedlings B 2903-17 and X 927-3 have several other common gene sources, but none of these likewise appears in 41956.

The opinion of the authors is that the surviving resistant seedlings of progeny Ia 1336 contain virus X immunity and that a similar type of immunity exists in Ia 55328, derived from the same cross.

Examination of the pedigrees in Figures 1-3 reveals some striking similarities. In all three pedigrees, varieties Sutton's Flourball, Aroostook Wonder (White Rose), and their derived seedling selection 24642 appear frequently. Selection 24642 is the male parent of Katahdin, a variety possessing high field resistance to virus X, but not graft immunity.

Insufficient information is available concerning the mechanism and method of inheritance of field resistance to virus X as typified by the variety Katahdin and the similarity or dissimilarity of field resistance to immunity as characterized in 41956. If these two forms of resistance are related and can be modified by manipulation of the genomic constitution, then it may be possible for breeders to incorporate virus X immunity with greater speed and efficiency. Further, certain lines of several *Solanum* species such as *S. acaule* Bitter, *S. rybinii* Juzep. & Buk., etc., have been

reported to contain individuals apparently immune from virus X which may or may not be a related source of immunity.

If further research substantiates the results reported herein, the appearance of virus X immunity in 41956 and 1a 1336 suggests a breeding principle of immeasurable importance. If it is possible in the case of virus X to combine genes from susceptible varieties and produce immunity, then a high degree of optimism may be held that by similar means immunity from other plant viruses may be found. It would not be necessary then to search for resistance outside of the specific genus and species, but rather to characterize thoroughly all the clones of *S. tuberosum* presently available. The appearance of virus X immunity in 41956 was a unique event, but it would be even more unusual if this would be the only such example in potato research.

#### SUMMARY

Progeny in the cross of susceptible X 927-3 (female) potato by susceptible B 2903-17 (male) were found to possess resistance to infection by virus X mechanically inoculated into Irish potato. Preliminary evidence indicated a close similarity to or identity with the immunity from virus X demonstrated by 41956. Examination of the pedigrees of parental lines and the pedigree of 41956 showed several similarities, but no common source of resistance was involved, unless it be the USDA Seedling 24642. Previously proposed theories of the origin of immunity from virus X were discussed, and the authors suggest that although their findings can be explained by a dominant complimentary gene theory, insufficient information is available to support either this or the recessive gene theory.

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SOME COMMON STEM STREAKS OF POTATO<sup>1</sup>D. B. ROBINSON<sup>2</sup>, G. D. EASTON<sup>3</sup> AND R. H. LARSON<sup>3</sup>

Stem streaking is a symptom common to several disorders of the potato plant. These include infection by certain strains of virus Y (2), and by the fungi *Verticillium albo-atrum* R. & B. (4), *Phytophthora infestans* Mont. (DeBary) and *Rhizoctonia* (6). A severe stem streaking has also been reported to result from an excess supply of manganese (1, 3). *Rhizoctonia* stem lesions are distinctive because of their occurrence at ground level and in relation to the newly developing underground shoots, but the stem streaks incited by *Phytophthora*, *Verticillium*, virus Y and excesses of manganese all affect the upper parts of the plant and are superficially quite similar in appearance at some stages. They are all quite common in some seed-potato producing areas so that it is important to recognize each when assessing disease incidence. This paper reports some characteristics that have been observed to distinguish the stem lesion symptoms of each of the above four common disorders.

*Late blight streak (P. infestans):* Usually this symptom is accompanied by the characteristic late blight lesions on the leaves but, as has been pointed out (6), unfavorable weather conditions may check the progress of the disease so that the usual leaf lesions of blight disappear. In such cases the most prominent symptom is often the brown, slightly sunken stem and petiole lesions. These are characterized by the diffuse margins and by the rapid penetration of the fungus through the cortex (Figure 1), so that streaks on opposite sides of the stem are often connected by underlying infected tissue. Typical late blight fructification on the stem lesions after 24 hours at about 68° C. in a moist chamber is the most certain means of identification.

*Verticillium streak (V. albo-atrum):* These lesions (Figure 2) have been described for the varieties Irish Cobbler and Sebago (4). They are dark brown, elongated and slightly sunken, with definite margins that may later coalesce into large lesioned areas. In cross section the tissue exhibits localized necrotic areas in both pith and cortex, often in juxtaposition to the infected vascular tissue. Characteristic of this streak is its presence at the junction of the stem and petiole, sometimes resulting in the abscission of the lower leaves of affected plants. Typical fructifications of the fungus will appear in lesions after 48 hours in a moist chamber at room temperature.

*Manganese toxicity streak:* Often called stem streak necrosis (1, 3), the streak caused by an excess of manganese usually begins as a necrotic flecking on stems and petioles that soon develop into long, narrow streaks

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<sup>2</sup>Research Laboratory, Canada Agriculture, Charlottetown, Prince Edward Island.

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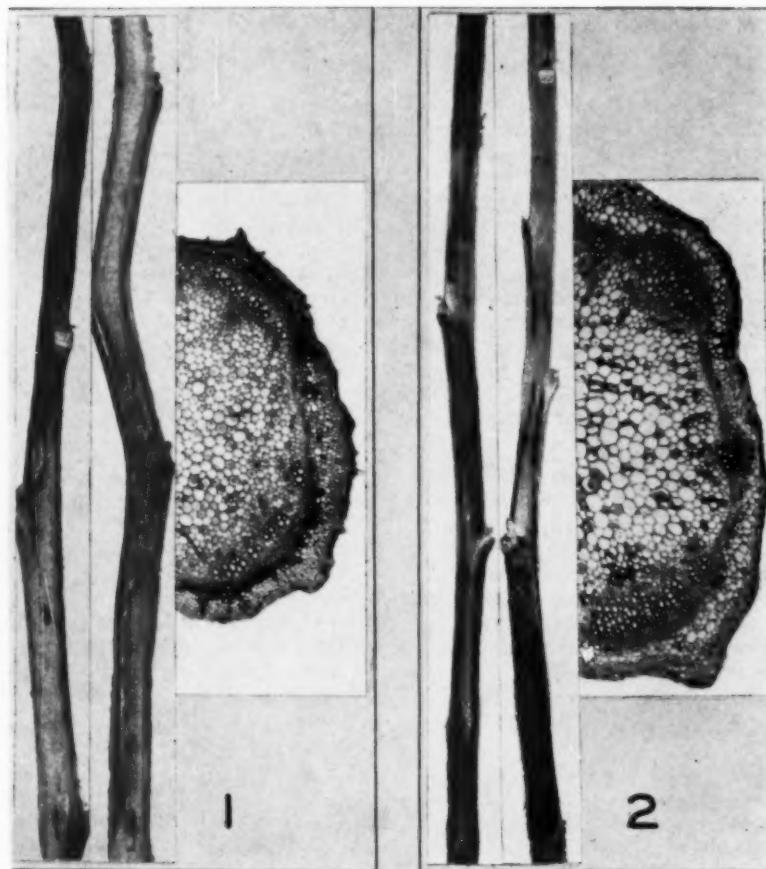


FIGURE 1.—Streak on Irish Cobbler incited by *P. infestans*.

FIGURE 2.—Streak on Irish Cobbler incited by *V. albo-atrum*.

(Figure 3). The necrosis is confined in the early stages to the epidermal cells, as shown in cross section in Figure 3, but later extends inward to involve the pith and ray cells, although only slightly injuring the vascular tissue (5). In later stages complete stem browning and leaf abscission occur, but stem streak necrosis is usually distinguishable by the early flecking of stems, petioles and sometimes leaves.

*Virus Y streak:* Certain severe isolates of virus Y cause a petiole and stem streaking (2). This streak differs from those described above in that whole areas of stem become more or less uniformly affected (Figure

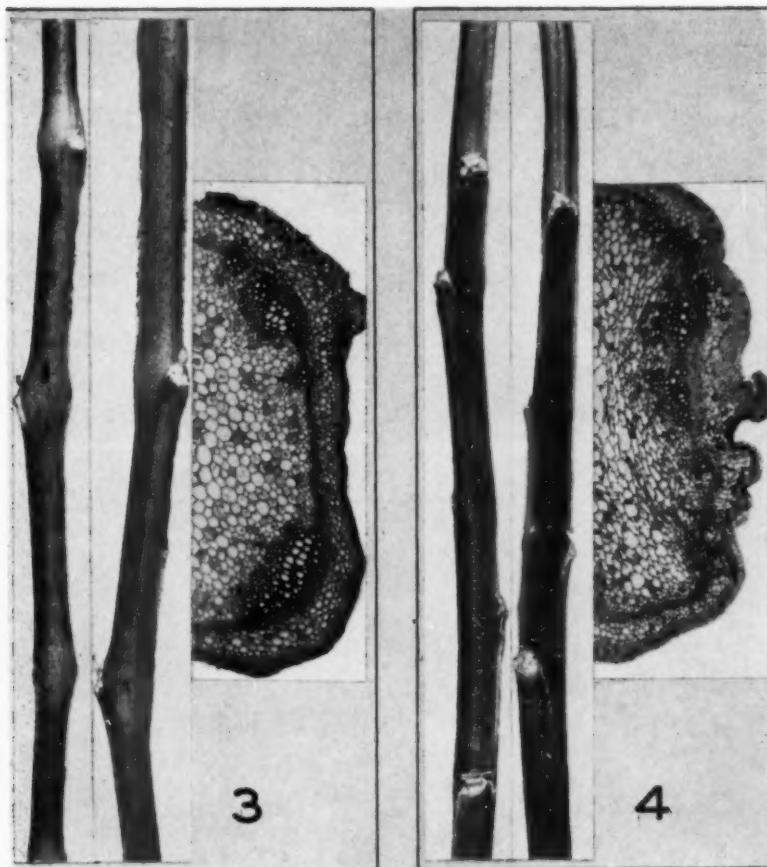


FIGURE 3.—Manganese toxicity streak on Irish Cobbler.

FIGURE 4.—Virus Y streak on Pontiac.

4). Cross sections about six weeks after inoculation show a general scattering of necrotic tissue throughout the stem. In contrast to the leaf abscission that often accompanies *Verticillium* and manganese streak, the leaves of virus Y affected plants may drop but leave the petiole still attached to the stem.

No critical comparison of varieties with respect to their susceptibility to these various streaks has been made, but observation has shown that wide differences do exist. For example, the varieties Irish Cobbler and Sebago will develop severe late blight, *Verticillium*, or manganese streak



FIGURE 5.—The effect of an excess of manganese on the development of *Verticillium* symptoms in Irish Cobbler potato.

Upper left: Inoculated plants in a low-manganese soil.

Upper right: Uninoculated control.

Lower left: Inoculated plants in a high-manganese soil.

Lower right: Uninoculated control.

but only slight streak from virus Y infection. The variety Pontiac develops severe virus Y streak but is quite resistant to manganese toxicity streak.

#### MATERIALS AND METHODS

As reported elsewhere (4), *Verticillium* stem streaking is markedly increased by high levels of moisture and fertility, conditions that favor complete invasion of the host by the pathogen. Also, this streak has been induced only in sandy loam soils, and in field plantings, has been observed

in such soils only in regions where manganese toxicity streak has been reported to occur. The possibility of an inter-relationship between *Verticillium* and manganese toxicity streak was studied in the greenhouse. In one such trial a completely fertilized sandy loam soil was sub-divided into two lots adjusted to a low and high level of manganese nutrition by adding increments of calcitic lime and manganese sulphate, respectively. Each of these lots was further subdivided to give a low and high level of soil moisture. These various lots of soil were then planted with the variety Irish Cobbler, using plants of uniform size that had been previously grown in quartz sand watered with a complete nutrient solution. At the time of transplanting, the seed pieces were removed and half the plants in each treatment were inoculated with *V. albo-atrum* by dipping the roots in a heavy conidial suspension of the pathogen.

#### RESULTS

Both wilt and streak began to appear in four weeks in some of the inoculated plants and increased steadily in severity. In this soil the manganese application used was not heavy enough to cause manganese streak in the non-inoculated plants so that the streak symptoms which developed were classed as *Verticillium* streak. Some data taken 48 days after transplanting are given in Table 1. It is notable that the appearance and development of wilting was much more rapid in the high moisture—high manganese treatment, although ultimately the severity of wilt became equal in all inoculated plants (Figure 5). Serial stem platings up to six inches above soil level in all inoculated plants showed that every one, both streaked and non-streaked, was completely invaded by the fungus. Also, tissue analysis of oven-dried foliage, using a colorimetric method (7), showed no significant difference in uptake of manganese attributable to inoculation with *Verticillium*. Both healthy and diseased plants grown on limed soil contained 50-70 ppm manganese; those grown in soil treated with manganese sulfate contained 240-290 ppm manganese.

TABLE 1.—Effect of two levels of moisture and manganese nutrition on *Verticillium* streak and wilt in Irish Cobbler potato seven weeks after inoculation.

Manganese <sup>1</sup> Level	Moisture <sup>2</sup> Level	Inoculated		Non-inoculated	
		Plants with Streak	Wilt <sup>3</sup> Index	Plants with Streak	Wilt <sup>3</sup> Index
Low	Low	0	0	0	0
	High	0	49.9	0	0
High	Low	1	4.2	0	0
	High	13	64.5	0	0

<sup>1</sup>Low levels of manganese given by calcitic limestone application of 3000 lbs./ac.; high level given by MnSO<sub>4</sub>.7H<sub>2</sub>O application of 100 lbs./ac.

<sup>2</sup>High moisture level near field capacity; low moisture half this level. All moisture levels maintained by daily pot weighings.

<sup>3</sup>Wilt indexes calculated as a severity rating of 16 plants in each treatment.

## DISCUSSION

These results, and those of similar trials, show that in some soils *Verticillium* streak may be induced by growing the inoculated plants at high levels of manganese nutrition. This effect of manganese in increasing the apparent severity of *Verticillium* infection may be the explanation of some hitherto inexplicable outbreaks of *Verticillium* streak in the field.

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NUTRIENT COMPOSITION OF WHITE ROSE POTATOES  
DURING GROWTH AND AFTER STORAGE<sup>1</sup>M. YAMAGUCHI, JAMES W. PERDUE, AND JOHN H. MACGILLIVRAY<sup>2</sup>

California produces late-spring and early-summer crops of White Rose potatoes for eastern and other markets. Over the years the crop has been harvested at various degrees of immaturity. At present most marketed tubers are of mature size and U. S. No. 1 grade, but much skin is rubbed off in harvesting and packing. Studies were initiated to learn the effect of maturity and storage at two different temperatures on nutrient content.

An examination of potato literature failed to produce any papers that give a complete analysis of nutrients at different maturities. As a potato matures, water and sugar decreases and protein and starch content increase (2). Mature potatoes in storage undergo a decrease in ascorbic acid content and a slight decrease in dry matter (1).

## MATERIALS AND METHODS

White Rose potatoes were planted in early April in Yolo fine sandy loam at Davis, California. The beds had been fertilized with 100 pounds of nitrogen per acre from ammonium sulfate applied broadcast. Irrigation practice was normal for the Davis area.

Beginning 60 days after planting, tubers were collected at 15-day intervals from 20 to 30 plants, depending on tuber size. Final harvest was on August 17, 75 days after the first harvest. Maximum size and shipping maturity was reached at the July 19th sampling. The potatoes were stored at 41 and 50° F. Tubers from the 41° F. storage were sampled for 30 weeks at intervals of 3 to 6 weeks. The 50° F. storage tubers were analyzed after 18, 24, and 30 weeks of storage. Only sound tubers were analyzed.

At each sampling, 25 to 30 tubers were randomly selected and analyzed. The tubers were peeled, and duplicate samples were collected for each of the following nutrients: total sugars, starch, protein, calcium, iron, phosphorus, ascorbic acid (vitamin C), thiamine (vitamin B<sub>1</sub>), riboflavin (vitamin B<sub>2</sub>), and niacin. White potatoes contain little or no vitamin A (8) therefore, were not analyzed for this constituent.

The methods of analysis were as follows:

Water:—Fifty grams of a fresh sample were dried 36 to 48 hours in a forced-draft oven at 65° C. Weight loss was taken as water.

Energy:—Total energy was calculated from total sugars, starches, fats, and proteins according to Sherman's technique (7, p. 135). Total sugars and starches were determined by methods of the Association of Official Agricultural Chemists (4, p. 132:12.49; 12.51; 12.52; 12.53). Starch was determined on the alcohol-extracted residue, using diastase extract instead of malt extract.

Protein, Calcium, Phosphorus, and Iron:—These were determined by

<sup>1</sup>Accepted for publication October 6, 1959.

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TABLE 1.—*Nutritive value of White Rose potatoes grown at Davis at different stages of growth.*

Harvest Date	Av. Wt. per Tuber Grams	Days after planting	Av. Wt. per Tuber Grams	Water Grams	Total Sugars Grams	Starch Grams	Protein Grams	Energy Per 100 Grams	Minerals			Vitamins					
									Calories	Grams	Edible Portion	Ca Mg	Fe Mg	P Mg	C Mg	B <sub>1</sub> Mg	B <sub>2</sub> Mg
June 7	60	50	85.3	0.75	8.12	1.90	43.7	13	3.1	3.7	3.8	0.044	0.019	0.57			
June 21	75	115	85.0	0.88	8.92	1.73	46.7	10	1.3	3.2	4.3	0.072	0.019	0.72			
July 5	90	140	84.3	0.98	10.45	1.86	53.7	12	2.0	3.7	4.2	0.093	0.016	0.68			
July 19*	105	155	81.8	0.28	12.61	2.10	40.7	11	1.8	4.5	4.8	0.106	0.024	0.62			
Aug. 8	120	175	81.6	0.18	11.52	2.09	56.0	12	1.9	4.5	3.9	0.101	0.023	0.67			
Aug. 17	135	192	80.8	0.25	11.86	2.37	58.7	14	2.0	5.3	3.6	0.117	0.025	0.66			

\*Usual shipping maturity for Kern County potatoes.

TABLE 2.—Nutritive value of mature White Rose potatoes grown and stored at Davis, California.

	Water Grams	Total Sugars Grams	Starch Grams	Protein Grams	Energy Kg. Calories	Minerals			Vitamins		
						Ca Mg	Fe Mg	P Mg	C Mg	B <sub>1</sub> Mg	B <sub>2</sub> Mg
At Harvest 8/17/49											
41° F. storage											
3 weeks	81	0.94	10.7	2.4	59	14	2.0	53	36	0.12	0.025
6 weeks	80	1.23	11.0	2.4	57	17	1.6	46	26	0.13	0.025
9 weeks	81	0.94	10.5	2.3	59	13	1.8	49	19	0.13	0.032
12 weeks	80	0.87	10.5	2.4	56	11	1.0	46	17	0.13	0.033
18 weeks	81	0.73	9.7	2.7	53	13	1.7	46	16	0.12	0.034
24 weeks	81	0.63	11.3	2.0	59	12	1.9	49	11	0.12	0.027
30 weeks	81	0.52	10.1	2.7	54	11	1.9	54	10	0.11	0.031
50° F. storage											
18 weeks	80	0.16	10.2	2.6	53	14	1.7	52	12	0.13	0.027
24 weeks	80	0.18	12.1	2.6	60	14	2.0	56	10	0.11	0.029
30 weeks	80	0.20	11.8	2.6	59	14	..	55	8	0.11	0.026

the methods of the Association of Official Agricultural Chemists (4:26, 2.24; 119, 12.12; 128, 12.40; 117, 12.7). 1-Amino-2-naphthol-4-sulfonic acid was substituted for hydroquinone as reducing agent in determining phosphorus.

Ascorbic Acid:—Ascorbic acid was determined by the method of Loeffler and Ponting (5). Included was dehydro-ascorbic acid, which was reduced to ascorbic acid by  $H_2S$ .

Thiamine and Riboflavin:—Thiamine and riboflavin were determined photofluorometrically by the procedure of the Association of Vitamin Chemists (3:189).

Niacin:—A microbiological method of the Association of Official Agricultural Chemists (4:617, 36.41-36.45) was used. Enzyme-hydrolyzed casein, as described by Roberts and Snell (6) was used in the basal medium instead of acid-hydrolyzed casein.

## RESULTS

Table 1 shows the change in nutritive value of the tubers during growth. The very immature potatoes were high in sugar content and low in starch. As the tubers matured, sugar decreased and dry weight, starch and protein increased. The vitamin C content increased to a maximum as the tubers approached maximum size and usual shipping maturity. Vitamin C decreased slightly as the tubers approached storage maturity. Thiamine ( $B_1$ ) and riboflavin ( $B_2$ ) increased with maturity, and niacin remained relatively constant.

Table 2 shows the nutritive values of potatoes stored for the various periods. Vitamin C decreased markedly during storage at 41 and 50° F. Changes in other constituents were not significant.

## SUMMARY

Potatoes were analyzed for nine food nutrients and energy as affected by maturity and storage period. As tubers approached maturity in the field, sugar and vitamin C decreased, and other nutrients increased. The principal change in storage was a loss in vitamin C.

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## NEWS AND REVIEWS

A BRIGHT FUTURE FOR POTATO DEHYDRATION IS  
WARRANTED<sup>1</sup>ANDREW MEDRICZKY<sup>2</sup>

The long awaited, recently published excellent reference and text book: W. H. Talburt and Ora Smith "Potato Processing", The AVI Publishing Co., 1959, gives a correct overall picture about the rapid development of the American potato processing industry, established between the two wars from a militarily promoted war-industry to a prosperous peace-time success. In the instructive introductory chapter on, History of Potato Processing, Dr. Talburt remarks, in relation to the present low 100 pounds per capita annual consumption, that "There is reason to believe that (by) the greater availability of a larger variety of processed products, (the) per capita consumption of potatoes may rise in the future." And further, he replies to the question of the potato producers on the Future of Potato Processing: "To provide an answer to this question is obviously a complex task for which more information is needed than is now available."

I take the liberty—as a food economist and technologist, who has been closely connected with the practical economic problems of the potato and soybean for human food, at first in Hungary, then in post-war Germany—to submit some experiences, thoughts and suggestions for such additional information. My remarks are restricted to the dehydration activity proper: mashed potatoes, both granules and flakes, dices, slices and strips, disregarding the splendid and profitable chips, puffs, canned and frozen products which are fully justified in our present high standard of living. The heartening fact that the housewives and bulk consumers are already "sold" on those dehydrated products, proves their good quality above any doubt. It is a triumph indeed, over the obsolete prejudices against any kind of dehydrated foods and perhaps more particularly, against dried potatoes.

The most crucial problem of the entire potato economy for human food is to find an applicable economical solution to dehydration. Each one hundred-weight of potatoes brings forth from the soil 4,500,000 calories, with 200 pounds biologically complete protein, 109 pounds mostly alkaline, base-forming minerals, certain amounts of various vitamins, mostly C vitamins. The transformation of the perishable potatoes into a non-perishable form can be conducted with a higher concentration of nearly all the nutrient ingredients, including those in the cortex layers. In this improved form the low, two per cent protein content will be raised to eight per cent which is about the same amount as that of rice, but in biologically higher quality. Therefore, for any enlightened food economist the endeavor to find a suitable preservation method for the potato, is a problem which surmounts the American market requirements and interests. It will disclose a hitherto unknown abundant source of durable and palatable, nourishing food which will ease the food shortage in many parts of the world to a considerable degree. The almost 2,000 years old cheapest

<sup>1</sup>Accepted for publication October 1, 1959.

<sup>2</sup>Free lance economist and food technologist, Fort Lauderdale, Fla.

"natural way" of dehydration by alternate freezing and thawing for several weeks duration, is only practicable under peculiar climatic conditions like the Andes mountain. (See American Potato Journal, August 1955, Dr. Treadway, *et al.*) On the other hand, modern industrial dehydration is still young and has yet has not reached its peak possibilities as yet.

According to my sources of information, the beginning of this modern industrial potato dehydration was originated by the prize-contests in 1894 and 1902, of the Association of Alcohol Manufacturers in Germany, for the best and most economical methods to make Trockenkartoffeln obviously with the main, though not exclusive, purpose to substitute the fresh potatoes with dried products in order to avoid idle seasons in alcohol plants. At the first contest, three; and at the second, five more methods were rewarded which gave such an impetus that by World War I, 51 processes and implements were developed. The number of plants rose from 3 in 1903, to 762 in 1915. All these plants, together with the official agricultural circles and industrial organizations have made a really great effort for the past 65 years to popularize their dried products, they even changed the work Trockenkartoffeln (dried potato) to Dauerkartoffeln (durable potato) for purely psychological reasons. But, except during wars and emergencies, a general popularity in Germany, could not be achieved. The plants produced mainly for industrial and animal feeding purposes. Public opinion was dissatisfied with any ersatz, substitute with sulfite blanching. The science only partly could verify this aversion by acknowledging the fact that the—so far—128 distinguishable components in the fresh potato are in natural equilibrium. Any man-made interference irreversibly disturbs it,—thus, in taste and quality, never again a hundred per cent equal substitution for fresh potatoes can be achieved. None the less, in the American products this quality difference has almost disappeared and the increasing marketing success proves that our consumers are willing to accept the very slight "deficiency". This is balanced out overwhelmingly by the enormous practical advantages of convenience, better storability, durability, and, in particular, saving of time and effort in preparing mashed, hash browned, French fried potatoes, *etc.*

But, on the other hand, there is a simple reason why peoples of the more potato-conscious countries like Germany, in spite of the continuous "brain-washing" publicity, are still reluctant to use the conventional substitute potato products. They know the potato better and they use it in the fresh stage in many ways. Not only as a side-dish, but for many main-dishes, sweet dishes, *etc.* During my long research and observation of the potato economy, I could have collected 250 fresh potato recipes from the culinary practice of various nations. This surprisingly wide versatility of the potato manifests the still unexplored and unexploited potentiality which can warrant a bright future for the discerning dehydrating industry. Basic food products are always more highly appraised by their variability against the monotonousness of our bills of fare. Would it not be a complacency for any unbiased mind to content himself with the present stage of potato dehydration, when it restricts the many ways of utilization of fresh potatoes to five or six side-dishes in the dehydrated form? From the point of view of food economy and food supply would it not be too high a price for dehydration?

Based upon indisputable facts, in my opinion, the potato dehydrating industry just has to set itself free from the one-sidedness of the substitution principle and to complement it for the sake of wider versatility, with a simple "new principle". They should produce, beside the current products, such products which are above the substitution principle; not only dehydrated, but also converted or transformed products ready for many ways of use. Between these two business policies a gap is recognized and this gap must be filled intelligently. There is always a fundamental difference between "mere inventions" and the discovery of a "new principle."

Without any exaggeration, after my experiences I feel that somewhat the same versatile pattern can be attained with appropriately processed potatoes as is obtained with processed wheat. By an intelligent policy, beside the potential direct consumers' sales, these products can also be gradually absorbed in larger and larger proportion by an enlightened and advised, further-processing industry. It can not be repeated often enough that the suggested "new principle" policy is merely a new chapter, an expansion of the present dehydrating activity. The more versatile suggested products will not compete at all with the present, non-versatile substitute products in any respect, because the utilization of each group has quite a different tendency.

The starting point of this suggested "new principle" was the early recognition in Germany in 1946 of the simple fact that the hitherto unused form of coarser grits, separated into rice and the farina like grades, provides the clue for such a wider versatility. Though the tasty pancake mixes of German origin, are not aimed and adjusted to this versatility principle, nevertheless, they can serve as one example of the successful new utilization program, as well as of the further-processing industry planning. I made such coarser grits in different ways. They were versatile but diverging in quality, taste, food value, consistency, and accordingly, in potential utilization. First, it was made from raw potatoes by a process lasting about three days. In those post-war years I did not continue the experiments because of the great losses in nutrients. Second, I experimented by crushing and screening of conventionally-treated and dried dices, slices and strips. The products had less taste and were sulfited, therefore I discontinued these too.

Finally, the third way was my "Method of Preparing a Granular Food Product from Potatoes", which, ultimately obtained the U. S. patent on July 9, 1957, and the Canadian patent, on November 11, 1958. Technologically, this method contains but seemingly minor, nevertheless essential differences from the usual approximately 100 known processes which by and large, all must follow the same major processing steps with certain individual modifications. The method is, like any other potato processing method, still subject to possible steady improving evolution, without departing however, from the basic intention: the preservation of the whole potato substance by transformation into a genuinely versatile coarse grits form, saving as much as possible of the water-soluble and heat susceptible ingredients. It also makes it possible to co-process the potatoes with any properly prepared fortifying and flavoring material in unlimited combination and cross-combination, with several of the agricultural "surplus-products" like milk-solids, egg-solids, and even with certain meat products. This alone

opens a hitherto unknown wide ramification for both the primary processing, and the further-processing industries. Although in the original process no chemical preserving sulfite was used, the original samples, made in a pilot plant in Germany in 1949, are still fresh and palatable, without any off color or off flavor. Modern nutritionists appreciate this "no chemicals added" fact, as well as the smooth chewability of the properly prepared grits, which promote the better salination, digestion, and satiation. The easy, quick, preparation of this concentrated foodstuff in numerous ways, is important for any bulk consumer when costs, time, labor, effort, fuel, space, and implements need to be considered: Armed Forces, Red Cross, Civil Defense, emergency mass-feedings, institutions, school children feeding, etc. The direct use is many-sided: as a complete or mixed morning porridge, appetizer, soup ingredient, side dishes, main dishes in unlimited variations, sweet dishes,—even as instant cocoa and fruit pudding, etc.; in a short time prepared complete dinners, indeed "from soup to nuts" were served several times to outstanding American, and foreign food experts, authorities. Also the advantageous use as an improving additive to bread, doughs, cookies, cake mixes, etc., was tested with surprisingly good effect.

The most fertile ideas are often very simple indeed—like the egg of Columbus—or as was the idea of quick frozen foods for which the late Clarence Birdseye had to wait for thirteen years, from 1916 to 1929, for full success. And today, beside the original pioneering company, not less than 1500 frozen foods packers and processors are flourishing upon that simple principle. One should not forget that there also, the method itself was only a part of the "new concept" of the frozen foods era, based upon enlightened, unbiased, technical, economic and market analysis—which brought the first profit after eleven more years.

My own investigations on the "wholeness" of the suggested new principle, also revealed in a much lesser extent, a bright ramification of the obvious, and still hidden possibilities. In their unfolding, the salesman's smartness can never replace the experience of the broader seeing economist and a true food scientist. The necessary knowledge must be patiently accumulated over several years of study, observation, experiment, investigation, and eye-opening discussions in person and in correspondence, to result in a sound judgment of the marketing possibilities and in a rationally elaborated strategical sequence of the individual steps.

As it seems now, the time has come with the plain probability that the present potato dehydrating practice has reached its limits, and in a "larger variety of the available processed products" is indicated in order to warrant the bright future of the industry, together with the increase of the *per capita* potato consumption. In my well-founded opinion I am convinced that the wholeness of the suggested new principle will comply with both requirements.

## 1960 MEETING, POTATO ASSOCIATION OF AMERICA

The joint meetings with the American Phytopathological Society will be held this year at the American Baptist Assembly at Green Lake, Wisconsin, August 28-31. A potato tour for those interested will start things off Saturday, the 27th, with a visit to several research plots at the Hancock Branch Experiment Station. A tour of the central Wisconsin potato growing area to observe harvest and other operations will continue Sunday prior to going on to the Center for registration. A noon banquet is planned for Monday, the 29th. The facilities at the Center are very adequate and a large attendance is anticipated. Meals and lodging for families will be available, and recreation at the camp is extensive and diversified. Special tours and other activities are planned for those not actually attending the sessions, *i.e.*, wives, children, and friends. Complete details will be announced soon concerning transportation, reservations, and the entire program for the different sessions.

HENRY DARLING

## BOOK REVIEW

**PLANT PHYSIOLOGY: A TREATISE. VOLUME II: PLANTS IN RELATION TO WATER AND SOLUTES.** Edited by F. C. Steward. This book is a comprehensive work dealing with the relationship of water and solutes to growing plants. The volume is divided into seven chapters covering respectively; cell membranes, water relations of cells, mechanism of stomatal movement, plants in relation to inorganic salts, translocation of organic solutes, translocation of inorganic solutes, and transpiration and the water economy of plants. Each chapter has been contributed by a prominent authority in the field of plant physiology. Among them are T. A. Bennett-Clark and J. F. Sutcliffe, University of London; O. Biddulph, State College of Washington; Runar Collander, Helsingfors University, Finland; O. V. S. Heath, Royal College of Science, England; Paul Kramer of Duke University, F. C. Steward of Cornell University, and C. A. Swanson of the University of Ohio.

The book level will appeal primarily to graduate plant physiologists rather than to undergraduates having their first introduction to the field. Each subject is reviewed historically and is outlined in considerable detail. Facts are well documented and bibliographies are complete and up-to-date.

Illustrations are exceptionally good with well-defined, easy-to-read graphs and tables and well-detailed sketches. Worthy of mention are the reproductions of autoradiograms showing the results of the use of radio-isotopes in studying the translocation of inorganic solutes.

This volume is a valuable reference for the trained plant physiologist and affords the type of source information which has long been sought for by researchers in the field.

Academic Press Inc., 111 Fifth Avenue, New York 3, N. Y. and 40 Pall Mall, London, S.W.1. Price \$22.00.

IDA A. LEONE, *Department of Plant Pathology, Rutgers Univ.*

### POTATOES IN A REDUCING DIET

Whatever else they may learn at Douglass College this year, 12 girls will not soon forget that they can eat a diet featuring a half-pound of potatoes a day and grow thin.

They know because they did it.

The girls were volunteers in an eight-week demonstration conducted by the Douglass Home Economics Department and financed by 11 state and national organizations of potato growers.

A report of the venture was recently made to New Jersey potato growers during a Farmers' Week session in Trenton.

Growers and Rutgers nutritionists have been concerned of late because figure-conscious consumers have been shunning the vitamin-and mineral-rich spud on the grounds that it's fattening. They don't mind the public's being figure-conscious but they don't like the potato to get the blame for the bulges.

It's a known fact that it's the gravy that runs up the calorie-count, they keep saying.

To prove their point, the nutritionists called for plump volunteers among Douglass students, girls who would be willing to stick to a diet in agreement with the traditional Douglass honor system spirit.

Response was tremendous, but one by one the group was whittled down to an even dozen young women whose excess weight ranged from 15 to 100 pounds.

Eligible dieters had to be at least 10 per cent overweight, and they had to agree to eat everything set before them and nothing else, except for occasional snacks of celery and carrots.

One girl didn't like eggs and another never ate pork, so they were dropped. Invitations to college house parties eliminated others. One of the final 12 turned down a weekend invitation to another college in favor of the diet table.

Dr. Miriam K. Brush of the Douglass Home Economics Department, who was in charge of the project, reports that when the girls sat down to their first low-calorie meal in the department's research laboratory, their weights ranged from 128 to 228 pounds.

When they weighed in at the end of eight weeks, the girls had lost an average of 14 pounds each. One was 25 pounds lighter.

Girls who have not yet scaled down to their ideal weights plan to continue with low-calorie foods selected from meals in the college dining hall.

"The girls say they found the potatoes satisfying and filling," Dr. Brush reports. "Potatoes were served in many different ways to give variety to the menu, and dishes often included butter 'borrowed' from some other part of the meal."

She said, the demonstration also proves that a reducing diet can be inexpensive, similar to what most families eat anyway and need not include special sweeteners or exotic foods.

Girls started the day with four ounces of orange juice, two-thirds cup of cooked or dry cereal, one slice of bread, a half pat of butter, six ounces of skim milk and black coffee.

A typical lunch consisted of potato salad made of one-half cup of

potatoes, three strips of carrots, one medium egg, lettuce, celery and one tablespoon low-fat mayonnaise per portion; one slice of bread, one half pat butter, six ounces of skim milk and medium serving of grapes.

Typical dinner: one-half cup boned chicken, one medium size potato, one-half cup green beans, one slice of bread, one-half pat butter, six ounces of skim milk and four halves of apricots.

A day's calorie count ran between 1150 and 1300 calories, depending upon the size of the girl. Results after eight weeks were 12 prettier, healthier and happier girls and a nation of potato growers who can say, "We told you so."

This project, conducted at Douglass College, Rutgers University, to demonstrate what nutritionists have long known, that potatoes are not fattening, was supported in part by The Potato Association of America. Your Editor was responsible for securing the financial aid needed to conduct the project. This news release has appeared in hundreds of newspapers, magazines and trade papers throughout the country. We believe that the serious reduction in the per capita consumption of potatoes in America during the last 25 years has been partially due to the false idea among millions of Americans that potatoes are fattening. It is hoped that this idea can be corrected through widespread reports, based on research, that potatoes are no more fattening than many other foods. It is the total number of calories consumed that determines whether one gains or loses weight. The potato has too many outstanding nutritive qualities to be dropped from the diet. We welcome the reprinting of this article by any publication.

We plan to publish a scientific report of this project in the near future.—*Editor.*

#### BONDE SCHOLARSHIP FUND

Members of the Department of Botany and Plant Pathology and other friends and associates of the late Dr. Reiner Bonde have established a scholarship fund to aid in the education of Dr. Bonde's children. The initial source of the fund was the residue remaining from unused contributions toward a floral offering by the Experiment Station. The "Bonde Scholarship Fund" is in the Merrill Trust Company Bank in Orono, and Dr. Richard Campana, Dr. Merle Hilborn, and Dr. Franklin Manzer have been designated as Treasurer and alternates. Contributions to the fund will be accepted from friends and associates of Dr. Bonde who may wish to contribute. Fund collections will be terminated by July 1, 1960, and the balance will be remitted to the custody of Mrs. Bonde for the purpose indicated.

*Richard Campana  
Franklin Manzer  
Merle Hilborn*

## BASIC RESEARCH ADVISED BY USDA'S POTATO RESEARCH AND MARKETING COMMITTEE

Basic research intended to improve the production, marketing, and utilization of potatoes was recommended by members of the U. S. Department of Agriculture's Potato Research and Marketing Advisory Committee at the committee's annual meeting in Philadelphia and Washington, Dec. 7-10.

Following its review of USDA's research program in potatoes, the committee assigned high priority to several proposals for new or expanded research, all basic in character. For example, it called for emphasis on breeding potatoes for varietal improvement, with particular attention to developing varieties suitable for specific types of processing and uses.

Basic research leading to improved disease control is also important, the committee said. Needed is information on the identity and behavior of bacteria, fungi, and viruses; potato plant physiology; resistance and susceptibility; manner of disease spread; and on treatments for disease prevention and cure.

In utilization research, the most important need is for studies that would yield new information on the chemical constituents that will advance potato processing. Applied research is also needed, to improve the quality and lower processing costs of potato chips, frozen French fries, canned and prepeeled potatoes, and potato granules and flakes, the committee noted.

Basic research is also the number one need in the marketing research area, the committee said. Top priority should go to fundamental research on postharvest physiology to improve potato storage practices. Knowledge of physiological responses and compositional changes in relation to temperature, pressure stresses, and physical handling will become more important as the proportion of the crop used in processing increases.

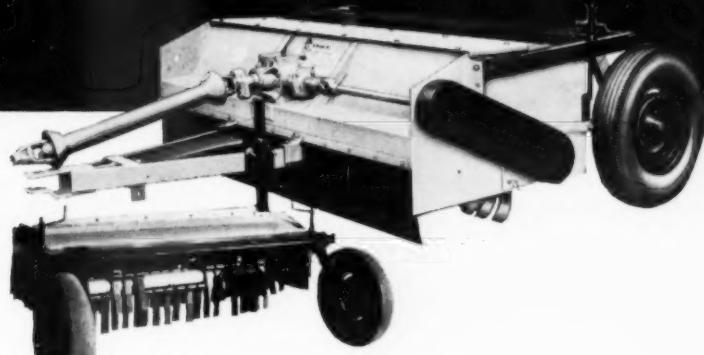
The committee also suggested that USDA develop improved statistical information on potatoes and expand its crop production and other statistical data to meet the needs of the potato industry more closely than is now possible.

Established under the Research and Marketing Act of 1946, the committee is made up of national leaders from the potato industry. Its detailed recommendations for potato research to be undertaken by USDA will be submitted formally to the Department within the next few weeks. Copies of this report will be available from the committee's executive secretary, Dr. Roy Magruder, Office of the Administrator, Agricultural Research Service, U. S. Department of Agriculture, Washington 25, D.C.

The committee spent one day viewing utilization research on potatoes at the Eastern Utilization Research and Development Division of USDA's Agricultural Research Service at Wyndmoor, Pa., outside of Philadelphia.

Loren Voth, partner in H. H. Voth and Sons, Wasco, Calif. grower and shipper, was named committee chairman to succeed Dr. James E. Kraus, director of the Idaho Agricultural Experiment Station at Moscow. A new vice-chairman, Ted Still, Monte Vista, Colo., grower and shipper, was named to succeed Mr. Voth.

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# Get higher yields — better chipping quality with Sul-Po-Mag

Protect your income two ways! Get bigger potato yields and excellent chipping quality with fast acting, water soluble Sul-Po-Mag.\* Double sulphate of potash-magnesia (Sul-Po-Mag) in your soil supplies magnesium needed for chlorophyll formation. That's why Sul-Po-Mag helps your plants produce more potatoes of full growth and maturity.

It also contains potash in the sulphate form rather than the chloride form. The sulphate form reduces the water content of the potato increasing desirability as a product for french fries and chippers.

You can market more potatoes. More markets are open to your potatoes.

## Magnesium Deficiencies

Special soil problems connected with potato growing make magnesium a critical element. Potatoes are usually grown on light, moderately acid soils — naturally low in magnesium.

Since magnesium deficiencies aren't visible until major damage has been done to the yields, regular program of soil testing and tissue testing should be followed to be sure that adequate supplies of magnesium are being added to the soil for maximum growth results. Sul-Po-Mag, unlike dolomitic limestone, does not change the soil acidity . . . therefore its use can not increase the danger of scab.

## Producers of Living Minerals



And, Sul-Po-Mag is granular. That means it dissolves at a controlled rate all season long to give growing plants the nutrients when they need them. Sul-Po-Mag provides proper balance between ready availability and lasting quality.

## Protect your yields

Lack of magnesium can lower your yields as much as 100 bushels per acre. Be sure you aren't losing income that your work and soil could bring you. Test for magnesium. Correct deficiencies by getting Sul-Po-Mag in the mixed fertilizers you buy. Talk to your county agent, talk to successful growers in your area, talk to your fertilizer dealer. Sul-Po-Mag in mixed fertilizer delivers the kind of results they'll be glad to tell you about.

\*Trademark. International Minerals & Chemical Corporation



Look for this identifying seal of approval when you buy. It's your assurance of extra-value fertilizer.

INTERNATIONAL MINERALS & CHEM. CORP.  
Dept. AP-43, Skokie, Ill.

Please send me a free copy of your "Magnesium" booklet which discusses magnesium and Sul-Po-Mag for specific crops.

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Now . . . you can do what leading potato growers do to help keep their plants healthy all season long

USE

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with exclusive U-101 for protection  
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## **CHEM-BAM**

For protecting plants against blight and other diseases. CHEM-BAM is the only liquid nabam fungicide with the exclusive U-101 chemical agent. U-101 makes CHEM-BAM stick to plants through rain and repeated waterings.

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For higher yields in every field. Healthier plants and bigger profits. You get increased yields and bigger profits because CHEM-BAM does a three-way job. CHEM-BAM spreads . . . CHEM-BAM wets . . . CHEM-BAM sticks.

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